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NOTES

ECONOMIC INTERPRETATION OF MAIZE FERTILIZER EXPERIMENT

During the last few years the use of fertilizers has increased many-fold. Fertilizer recommendations are generally made without giving full consideration to economic aspects. The profits from the use of fertilizer are increased as long as the cost of using additional fertilizer is covered by the added returns. The optimum level of fertilizer use is made when the marginal revenue equals marginal cost. The farmers are raising such questions as : how much fertilizer to use and how much it will pay by using fertilizer ? This study was made to answer such practical questions related to fertilizer use : (1) How much fertilizer to use ? (2) Least cost combinations of fertilizer for specified yield level at given fertilizer prices. (3) Optimum level of fertilizer when capital outlay is fixed.

Material and Methods

The data for this analysis were used from the fertilizer experiment conducted at the Indian Agricultural Research Institute, New Delhi on maize for five years (1949-53). Various levels of nitrogen, phosphorus and potash were tried with $3 \times 3 \times 2$ confounding design with two replications. The levels of N, K_2O and P_2O_5 used were :

N_0 = No nitrogen	P_0 = No phosphorus
N_1 = 40 lbs. nitrogen/acre	P_1 = 40 lbs. P_2O_5 /acre
N_2 = 80 lbs. nitrogen/acre	P_2 = 80 lbs. P_2O_5 /acre
	K_0 = No potash
	K_1 = 60 lbs. K_2O /acre

The data were subjected to analysis of variance which showed that N and P were significant at 1 per cent whereas their interaction was significant at 5 per cent level. Since K_2O was not significant, this analysis was confined to two factors, *i.e.*, N and P_2O_5 .

Production function approach was used for economic interpretation of the fertilizer response data. The quadratic surface function was used as this function gave combination of increasing as well as decreasing returns and also accounted for the interaction of the factors. The form of the function used was :

$$Y = a + b_1 X_1 + b_2 X_2 + b_3 X_1^2 + b_4 X_2^2 + b_5 X_1 X_2$$

The polynomial function was preferred to the exponential as well as power function because the latter functions did not explain for the interaction and also did not yield combination of increasing and decreasing returns.

Results and Discussion

The response equation developed from the five years' pooled data gave the following results :

$$Y = 6.228582^{**} + .083125^{**} N + .033764^{*} P - .0004689 N^2 - .0004013 P^2 + 0.002418 NP$$

$$(.288842) (.012507) (.012507) (.0001421) (.0001421) (.0001007)$$

$$R^2 = .9213$$

** Significant at 1 per cent level.

* Significant at 5 per cent level.

The results showed that all the coefficients in the equation were significant. As the value of the coefficient of multiple determination was quite high, it showed that the response equation gave a good fit.

Derived Yields

The derived yields were calculated at various levels of N and P_2O_5 and presented in a three dimensional diagram. The calculated yields as compared with the observed yields gave a close approximation which meant that the fitted function conformed very closely to the data. The calculated yields were also depicted on the graph showing the response of N and P_2O_5 at various levels of P_2O_5 and N. The derived yields are presented in Table I.

TABLE I—DERIVED YIELDS IN QUINTALS AT VARIOUS LEVELS OF N AND P_2O_5

P/N	N ₀	N ₂₀	N ₄₀	N ₆₀	N ₈₀	N ₁₀₀
P ₀	6.2286	7.7035	8.8032	9.5278	9.8772	9.8521
P ₂₀	6.7433	8.3150	9.5115	10.3327	10.7790	10.8504
P ₄₀	6.9370	8.6054	9.8987	10.8166	11.3597	11.5278
P ₈₀	6.9085	8.5747	9.9646	10.9794	11.6194	11.8840
P ₁₀₀	6.3610	8.2229	9.7096	10.8211	11.5579	11.9193

Table I as well as the Figures 1 to 3 indicated that the yields increased in the initial stages and ultimately diminished giving a concave shape to the response curve when one factor was varied and other was fixed. It was also apparent that the response curve was quite steep when the fixed factor was held high. The slices of the production surface also showed the same relationship.

Marginal Products

Marginal products due to N $\left(\frac{\partial Y}{\partial N}\right)$ and P_2O_5 $\left(\frac{\partial Y}{\partial P}\right)$ were calculated by taking partial derivative from the response curve at various levels of N and P_2O_5 .

$$Y = 6.228582 + .083125 N + .033764 P - .0004689 N^2 - .0004013 P^2 + .0002418 NP$$

$$\frac{\partial Y}{\partial N} = .083125 + .0002418 P - .0009378 N$$

$$\frac{\partial Y}{\partial P} = .033764 + .0002418 N - .0008026 P$$

$$Y = 6.22858 + .083125 N + .033764 P - .0004689 N^2 - .0004013 P^2 + .0002418 NP$$

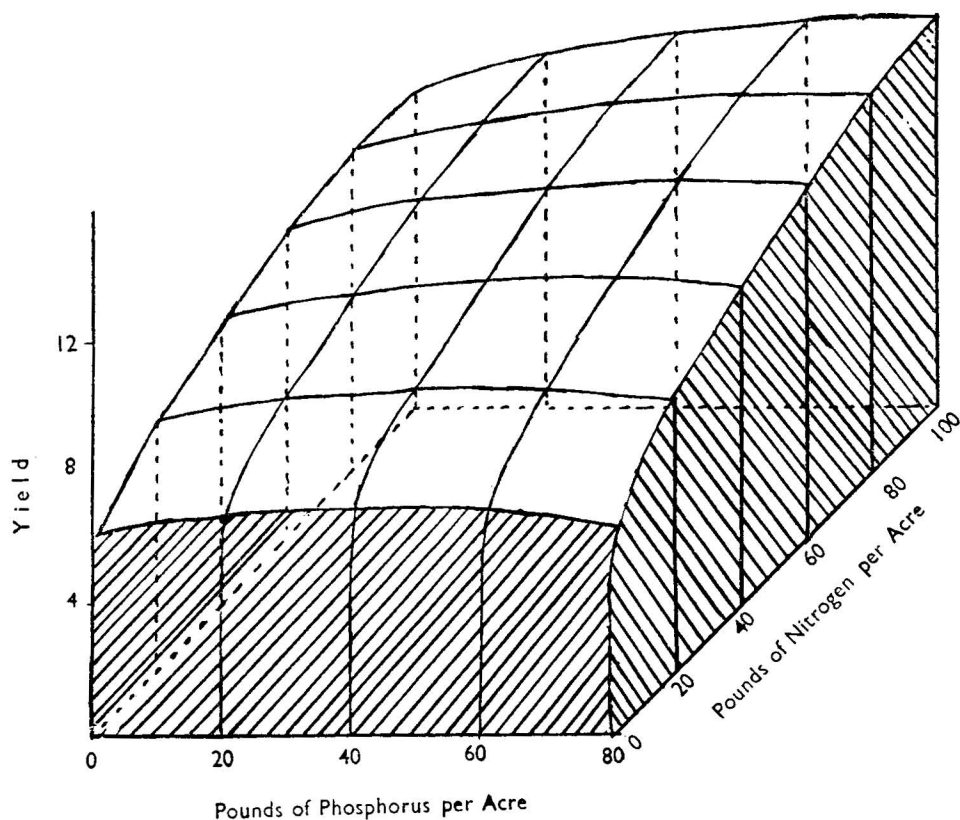


Figure 1—Predicted Yield Surface of Maize

The marginal products for different combinations of N and P_2O_5 were calculated and presented in Table II.

TABLE II—MARGINAL PRODUCTS FOR VARIOUS COMBINATIONS OF N AND P_2O_5

P/N				N_0	N_{20}	N_{40}	N_{60}	N_{80}	N_{100}
P_0	..	..	..	.0831	.0644	.0456	.0268	.0081	.0106
				.0338	.0386	.0435	.0483	.0531	.0579
P_{20}	..	..	..	.0879	.0692	.0504	.0317	.0129	.0058
				.177	.255	.0274	.0322	.0371	.0419
P_{40}	..	..	..	.0928	.0740	.0553	.0365	.0178	.0009
				.0016	.0085	.0113	.0162	.0210	.0258
P_{80}	..	..	..	.0976	.0789	.0601	.0414	.0226	.0039
				.0304	.0256	.0208	.0159	.0111	.0063

$$Y = 6.22858 + .083125 N + .033764 P - .0004689 N^2 - .0004013 P^2 + .0002418 NP$$

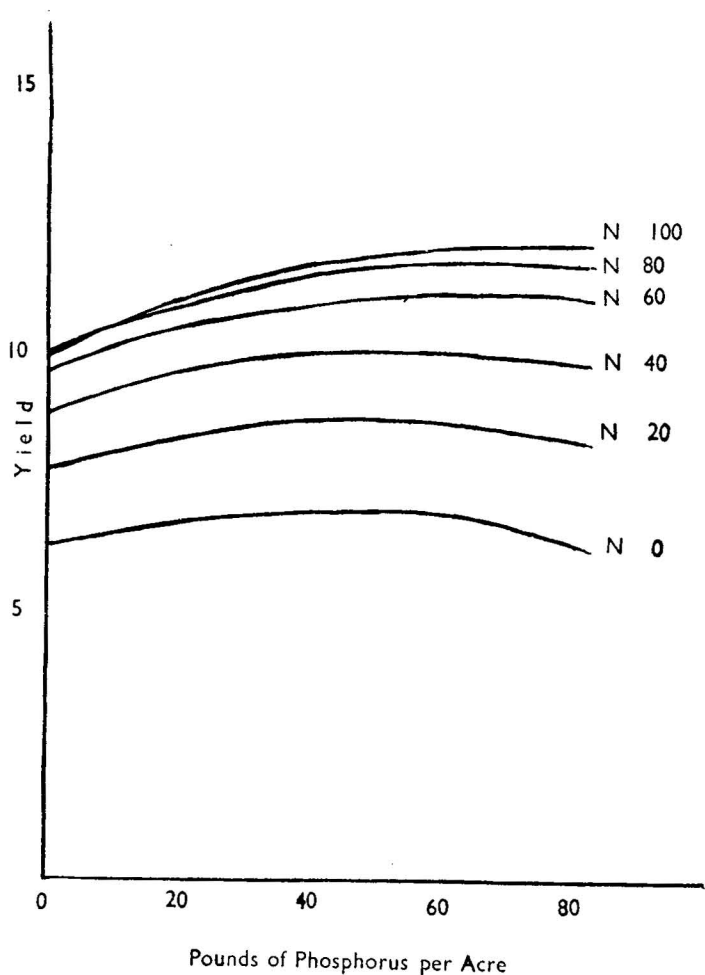


Figure 2—Maize Yield Response to Phosphorus at Various Levels of Nitrogen

Marginal products showed the rate of change in yield at different levels of N and P_2O_5 (Table II). Such data served as a good guide for taking a decision on the quantity of one factor to be used when other factor was fixed. It was also apparent that the marginal products due to N increased at higher levels of P_2O_5 and vice versa.

Maximum Yield

The maximum yield was obtained from the use of factors at the levels where the marginal products of the respective factor became zero. The levels were

$$Y = 6.22858 + .083125 N + .033764 P - .0004689 N^2 - .0004013 P^2 + .0002418 NP$$

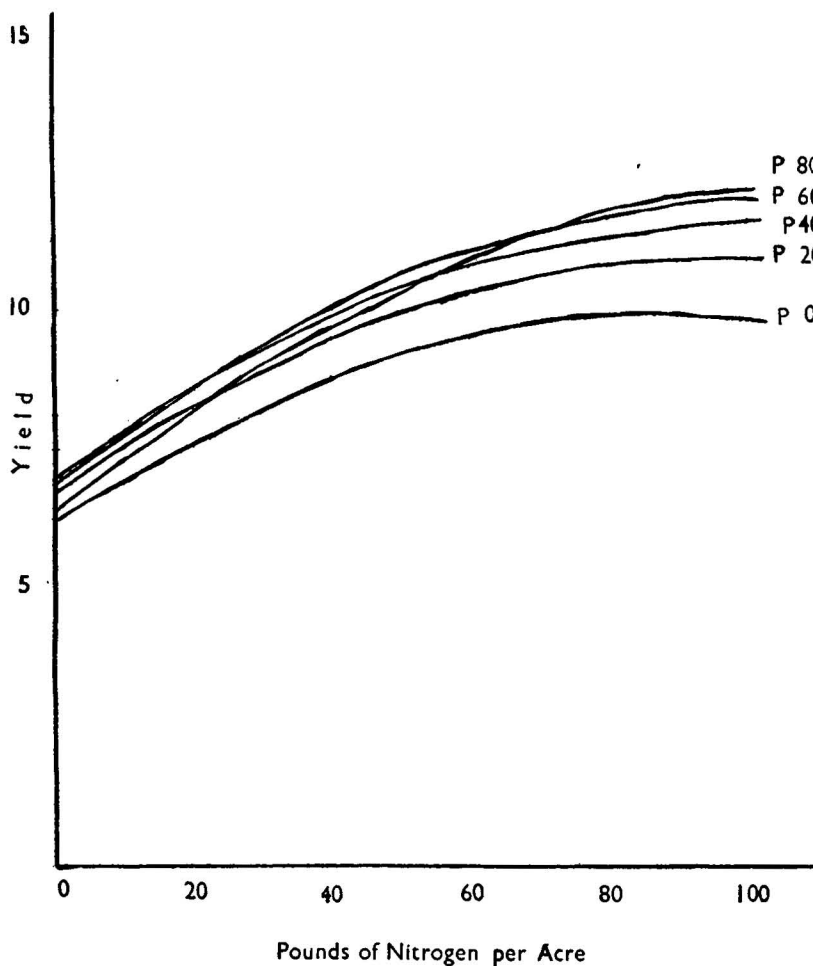


Figure 3—Maize Yield Response to Nitrogen at Various Levels of Phosphorus

calculated by solving the marginal product equations of both the factors simultaneously.

$$\frac{\partial Y}{\partial N} = .083125 + .0002418 P - .0009378 N = 0$$

$$\frac{\partial Y}{\partial P} = .033764 + .0002418 N - .0008026 P = 0$$

Solving these equations we get :

$$N = 106.86 \text{ lbs./acre}$$

$$P_2O_5 = 74.56 \text{ lbs./acre}$$

Calculated yield at these levels of N and P = 11.9693 quintals. Response over control = 5.7407 quintals.

The net returns over fertilizer cost at different prices of maize are presented in Table III.

TABLE III—NET RETURNS OVER FERTILIZER COST AT DIFFERENT PRICES OF MAIZE

Price of maize per quintal	Response over control (quintal)	Fertilizer* cost (Rs.)	Gross returns (Rs.)	Net returns over fertilizer cost (Rs.)
50.00	5.740725	144.04	287.04	143.00
55.00	„	„	315.74	171.70
60.00	„	„	344.44	200.40

*Price of Ammonium Sulphate = Rs. 360.00 per ton.
Price of Superphosphate (single) = Rs. 275.00 per ton.

Yield Isoquants

Iso curves were worked out for a yield range of 7, 9 and 11 quintals and are shown in Figure 4. These levels were calculated from the fitted response equation by setting it at the level for which the isoquant was intended to develop. The equation was then arranged as quadratic of one factor and at various levels of the other factor—the corresponding values were obtained by using the formula :

$$N = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

The various levels of N and P₂O₅ were worked out for specified yields levels (7, 9 and 11 quintals) and are presented in Table IV.

TABLE IV—VARIOUS LEVELS OF NITROGEN AND PHOSPHATE FOR DIFFERENT ISOQUANTS

N	9.824	2.963	.682	1.970	6.415
Y = 7.00					
P	0	20	40	60	80
N	44.518	30.692	25.523	25.576	29.810
Y = 9.00					
P	0	20	40	60	80
N	73.981	65.384	61.619	60.494	64.025
Y = 11.00					
P	30	40	50	60	80

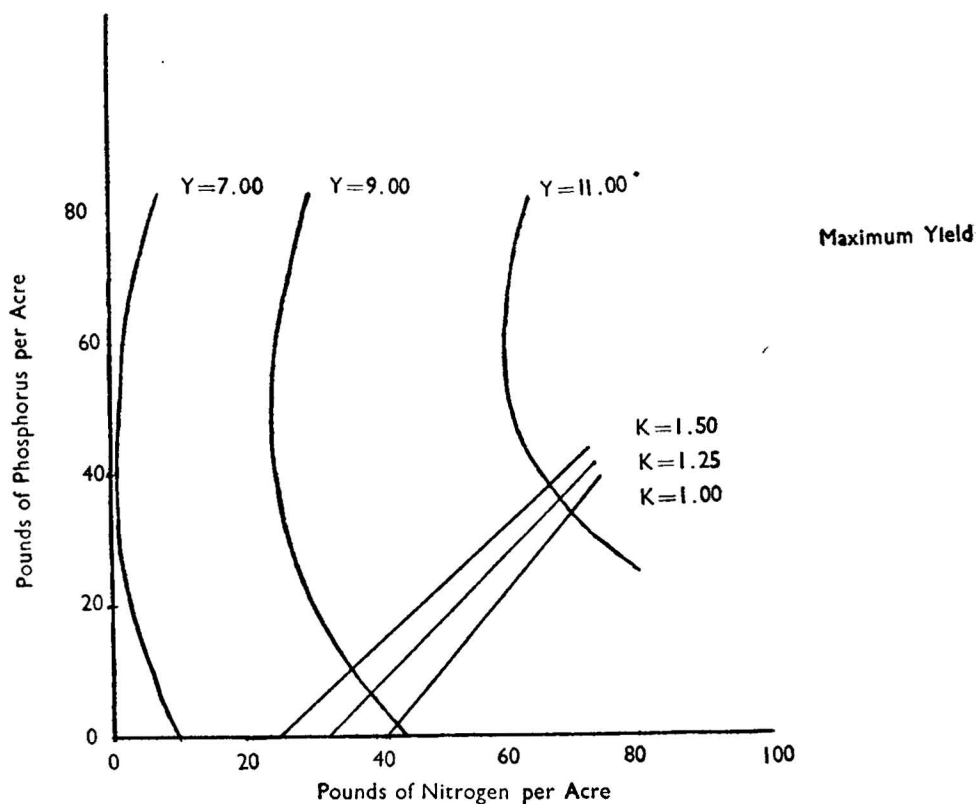


Figure 4—Yield Isoquants and Isoclines

It is apparent from Table IV and Figure 4 that the specified yield levels could be produced at various combinations of N and P_2O_5 . The shape of isoquants showed that the two factors were substituted in a very limited range. This is due to the reason that the marginal products due to P_2O_5 began to diminish even at lower levels of its application.

Marginal Rates of Substitution

The shape of the various yield isoproduct curves at various combination of nitrogen and phosphorus was estimated by calculating the marginal rates of substitution. The marginal rates of substitution were calculated as :

$$\frac{\partial P}{\partial N} = - \frac{\frac{\partial Y}{\partial N}}{\frac{\partial Y}{\partial P}}$$

$$\text{Numerically : } \frac{\partial P}{\partial N} = - \frac{.083125 + .0002418 P - .0009378 N}{.033764 + .0002418 N - .0008026 P}$$

The marginal rates of substitution for specified yield and for various combinations of N and P₂O₅ are presented in Table V.

TABLE V—MARGINAL RATES OF SUBSTITUTION AT SPECIFIED YIELD LEVELS

Yield quintals/acres	Pounds of nitrogen per acre	Pounds of phosphorus per acre	Marginal rates of substitution
7.00	9.824	0	— 2.0452
	5.718	10	— 2.9564
	2.963	20	— 4.6225
	.682	40	—49.8146
9.00	44.518	0	— 0.9292
	36.035	10	— 2.5021
	30.692	20	— 2.3546
	25.523	40	—37.6089
11.00	73.960	30	— .7616
	65.384	40	— 2.3079
	61.619	50	— 4.3864
	60.494	60	—174.0511

Yield Isoclines

The isoclines were estimated by setting the equation of marginal rate of substitution equal to their price ratios : $\left(\frac{\text{Price of N per unit}}{\text{Price of P}_2\text{O}_5 \text{ per unit}} \right)$. Under perfect competition, these isoclines were estimated at different price ratios (R), *i.e.*, 0.75, 1.00, 1.25 and 1.50 because these price ratios gave a practical range of the price variations of the factors :

$$\frac{\partial P}{\partial N} = \frac{.083125 + .0002418 P - .0009378 N}{.033764 + .0002418 N - .0008026 P} = \frac{CN}{CP} = R$$

The isoclines estimated at different price ratios are :

Price ratio	Isocline
0.75	P = 1.32640 N — 68.506074
1.00	P = 1.129452 N — 47.26543
1.25	P = .995984 N — 32.866150
1.50	P = .899564 N — 22.465933

These isoclines yielded the expansion path on which specified yield level could be produced at minimum cost.

Minimum Cost Combination

Minimum cost combination at given price ratios and for specified yield levels were calculated by solving isocline equations for the given price ratio along with the isoquant equation for the specified yield. The minimum cost combinations of N and P₂O₅ for different price ratios and for various yield levels are given in Table VI.

TABLE VI—MINIMUM COST COMBINATIONS OF N AND P₂O₅ AT DIFFERENT PRICE RATIOS AND SPECIFIED YIELD LEVELS

Price ratio	Yield level	Pounds of nitrogen	Pounds of phosphorus
1.00	9.00	43.0769	1.3907
	11.00	70.8379	32.7455
1.25	9.00	38.9883	5.9656
	11.00	68.5029	35.3616
1.50	9.00	36.0580	9.9705
	11.00	66.8190	37.6420

Profit Maximization

The optimum levels of fertilizer use were determined by solving the following equations simultaneously :

$$\frac{\partial Y}{\partial N} = \frac{cN}{cY} \quad \dots\dots\dots (i)$$

$$\frac{\partial Y}{\partial P} = \frac{cP}{cY} \quad \dots\dots\dots (ii)$$

$$i.e., \frac{\partial Y}{\partial N} = .083125 + .0002418 P - .0009378 N = \frac{cN}{cY} \quad \dots\dots\dots (i)$$

$$\frac{\partial Y}{\partial P} = .033764 + .0002419 N - .0008026 P = \frac{cP}{cY} \quad \dots\dots\dots (ii)$$

where cN = Price per lb. of nitrogen,
cP = Price per lb. of phosphorus,
cY = Price per quintal of maize.

As the prices of agricultural products experienced wide fluctuation over time, optimum levels of fertilizer use were calculated for a range of maize prices (Rs. 50.00, 55.00 and 60.00). The prices of nitrogen and phosphorus used were :

cN = .796550 per lb.
cP = .793784 per lb.

The optimum levels of N and P₂O₅ were worked out by solving equation (i and ii) at various prices of maize and were presented in Table VII.

TABLE VII—OPTIMUM COMBINATIONS OF N AND P₂O₅ FOR DIFFERENT PRICE LEVELS OF THE PRODUCT

Price of maize per quintal (Rs.)	Optimum levels of		Response over control (quintals)	Fertilizer cost (Rs.)	Net return over fertilizer (Rs.)	
	N (lbs.)	P ₂ O ₅ (lbs.)				
50.00	..	83.916	47.568	5.337	104.60	162.25
55.00	..	86.093	50.025	5.407	108.29	189.10
60.00	..	87.907	52.068	5.461	111.35	216.31

Optimum Dose for given Capital Outlay

In many cases the optimum doses of fertilizers may not be possible to apply due to financial handicaps and uncertainty. In such cases where capital was limited, the optimum level of fertilizer was determined from the interaction of the isocline corresponding to $\frac{cN}{cP} : cN.N + cP.P = C$ (Capital).

The solution was obtained by moving along the isocline until all capital was exhausted. In the present case $\frac{cN}{cP} = \frac{.796550}{.793784}$ and the corresponding isocline was:

$$\frac{\partial P}{\partial N} = \frac{.083125 + .0002418 P - .0009378 N}{.033764 + .0002418 N - .0008026 P} = \frac{.796550}{.793784}$$

$$.0011804 N - .0010472 P = .049243 \quad \dots\dots\dots (i)$$

$$.796550 N - .793784 P = C \quad \dots\dots\dots (ii)$$

The response and net returns over fertilizer use when capital outlay (C) was fixed at Rs. 50.00, 75.00 and 100.00 were calculated by solving the above equation for various levels of C and are presented in Table VIII.

TABLE VIII—OPTIMUM COMBINATIONS OF N AND P₂O₅ WITH CAPITAL OUTLAY FIXED

Capital outlay		Pounds of nitrogen	Pounds of phosphorus	Response over control	Price of maize per quintal	Net returns over fertilizer cost
50.00	..	51.633	11.177	3.4087	50.00	120.44
					55.00	137.48
					60.00	154.52
75.00	..	66.412	27.840	4.5285	50.00	151.43
					55.00	174.07
					60.00	196.71
100.00	..	81.196	44.500	5.2395	50.00	161.97
					55.00	188.17
					60.00	214.37

Summary

This agronomic trial on maize was conducted at Indian Agricultural Research Institute, New Delhi. The levels of nitrogen and phosphorus used in this experiment were 0, 40 and 80 lbs. each. Using the Production Function approach, economic interpretation of the data gave the optimum levels of nitrogen and phosphorus at 86.09 lbs. and 50.02 lbs. respectively. Economic interpretation of the production surfaces data were therefore necessary for making fertilizer recommendation to the farmers.

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AND

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PREDICTION OF FERTILIZER CONSUMPTION IN INDIA

There are several methods of predicting fertilizer consumption and each of these has its limitations. The more important of them are (i) potential method, (ii) regression method, and (iii) trend analysis method. In this note, a detailed study has been made in case of trend analysis method by using autoregressive series.

Trend Analysis Method

In order to study future prospects of fertilizer consumption, past data for the period 1951-52 to 1963-64 have been analysed and trend equations are fitted. This method has its limitations in as much as it depends only on the past performance and does not include any significant change which may happen in future. Under the circumstances like food crisis, special emphasis is to be given to fertilizers. These types of efforts can hardly be impounded in any statistical model and some realistic estimate, keeping in mind the trend projections, has to be found in such cases. Trend analysis does include these factors if the problem is not a new one and if such efforts were being made in the past as well.

With a view to find trend analysis we have taken year 1951-52 as zero (base), 1952-53 as 1 and so on and this is denoted by t . Thus t takes values 0, 1, 2, 3, . . . and so on, its value being 19 corresponding to the year 1970-71. Consumption of Nitrogen (N), Phosphorus (P) and Potash (K) is analysed separately as well as combined. Moving averages of order three has been taken in order to remove random fluctuations and as the result of which trend values are found. These trend values are denoted by Y_t corresponding to time t and trend equation fitted is $Y_t = a + b Y_{(t-1)}$. These equations are fitted with the help of least squares method and are given below :

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